

Figure 1A

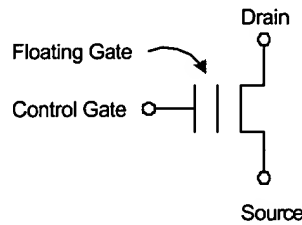


Figure 1B

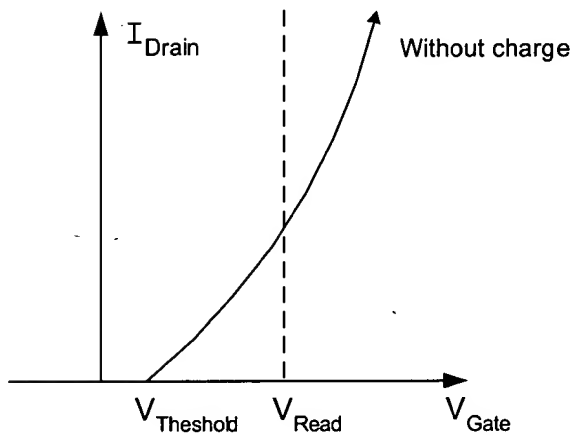


Figure 1C

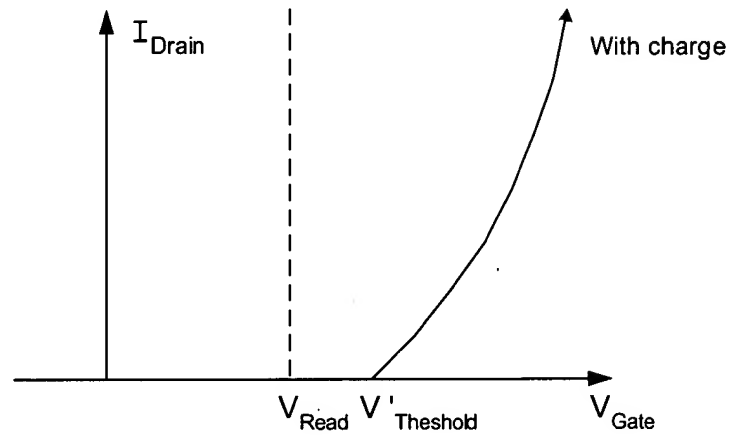


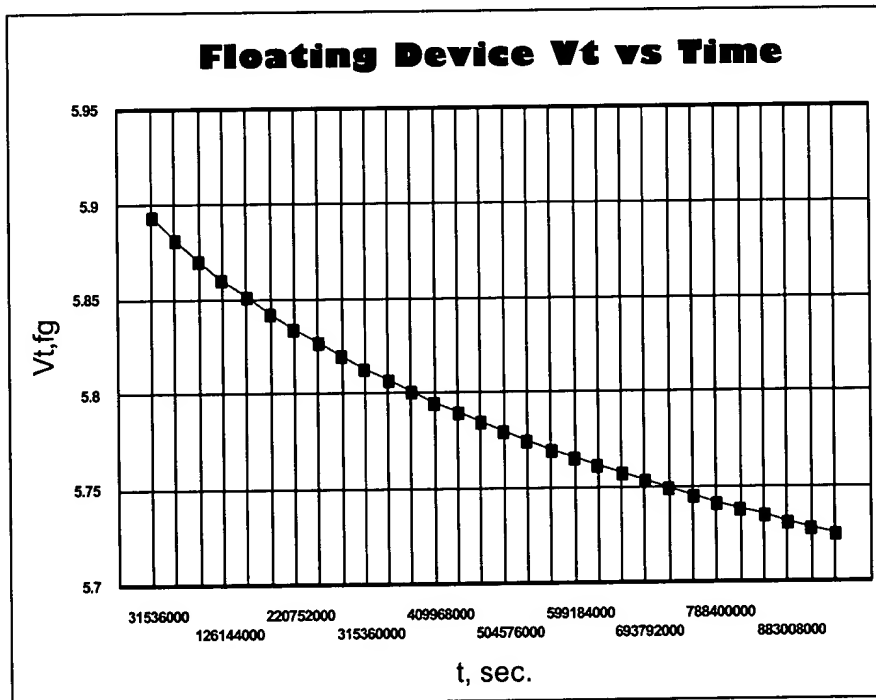
Figure 1D

Calculation of non-volatile memory cell retention characteristics

q0, C	m0, kg	kb, J/K	h, J-s	hb, J-s	Seconds	Time Period
1.6022E-019	9.1095E-031	1.38062E-023	6.62617E-034	1.054588E-034	31536000	1 year
					94608000	3 years
					1.89E+008	6 years
b0, eV (barrier)	e1	mr, effective mass ratio	T, K degree		2.84E+017	9 years
2.9		3.9	0.5	300	3.78E+008	12 years
					4.73E+008	15 years
					9.08E+009	18 years
C	b				6.62E+008	21 years
1.0630E-006	2.3854E+008				7.57E+008	24 years
					8.51E+008	27 years
					9.46E+008	30 years

Lfg um	0.6000	Channel length of floating gate device
Wfg um	1000.0000	Channel width of floating gate device
Hfg um	0.0900	Thickness of floating gate polysilicon conductor
Wrx um	0.5000	Width of floating gate overlapping shallow trench isolation
Ttunox A	80	Tunnel oxide thickness
Tono A	190	Thickness of Oxide-Nitride-Oxide dielectric between floating gate and control gate for capacitive coupling
Tswox A	300	Thickness of sidewall oxide between floating gate and control gate for sidewall coupling
Xfd um	0.0500	Length of floating gate overlapping drain region of the floating gate MOSFET
Xfs um	0.3500	Length of floating gate overlapping source region of the floating gate MOSFET
Ainj um2	0.0438	Area of the electron tunneling region between the floating gate and the source for resetting the floating gate charge
Cfc fF	1089.5358	Capacitance between the floating gate and the control gate
Cfsx fF	0.4313	Capacitance between the floating gate and the silicon substrate
Cfd fF	0.1078	Capacitance between the floating gate and the drain
Cfs fF	0.7547	Capacitance between the floating gate and the source
Cfg fF	1090.8295	Total floating gate capacitance
Cr,wi	0.9988	Control gate to floating gate coupling ratio
Cr,src	0.0007	Source junction to floating gate coupling ratio
Vt,fg V	0.90	Threshold voltage of floating gate MOSFET
Verase	0.00	Erase voltage applied to the source(not used here, set to zero)
Vfg,ini	-5.00	Initial floating charged voltage
Va	0.00	Actual erase voltage (equal to applied + charge stored on the floating)
S	3.76E+016	Derived parameter in the floating gate "erase" equation
X	1.27E+011	Derived parameter in the floating gate "erase" equation

t, sec.	Vt,fg
0.00001	5.907
31536000	5.894
63072000	5.882
94608000	5.871
1.26E+008	5.861
1.58E+008	5.852
1.89E+008	5.843
2.21E+008	5.835
2.52E+008	5.827
2.84E+008	5.820
3.15E+008	5.814
3.47E+008	5.807
3.78E+008	5.801
4.1E+008	5.795
4.42E+008	5.790
4.73E+008	5.785
5.05E+008	5.780
5.36E+008	5.775
5.68E+008	5.770
5.99E+008	5.766
6.31E+008	5.762
6.62E+008	5.757
6.94E+008	5.753
7.25E+008	5.750
7.57E+008	5.746
7.88E+008	5.742
8.2E+008	5.739
8.51E+008	5.735
8.83E+008	5.732
9.15E+008	5.729
9.46E+008	5.726



Figures 1E-1F

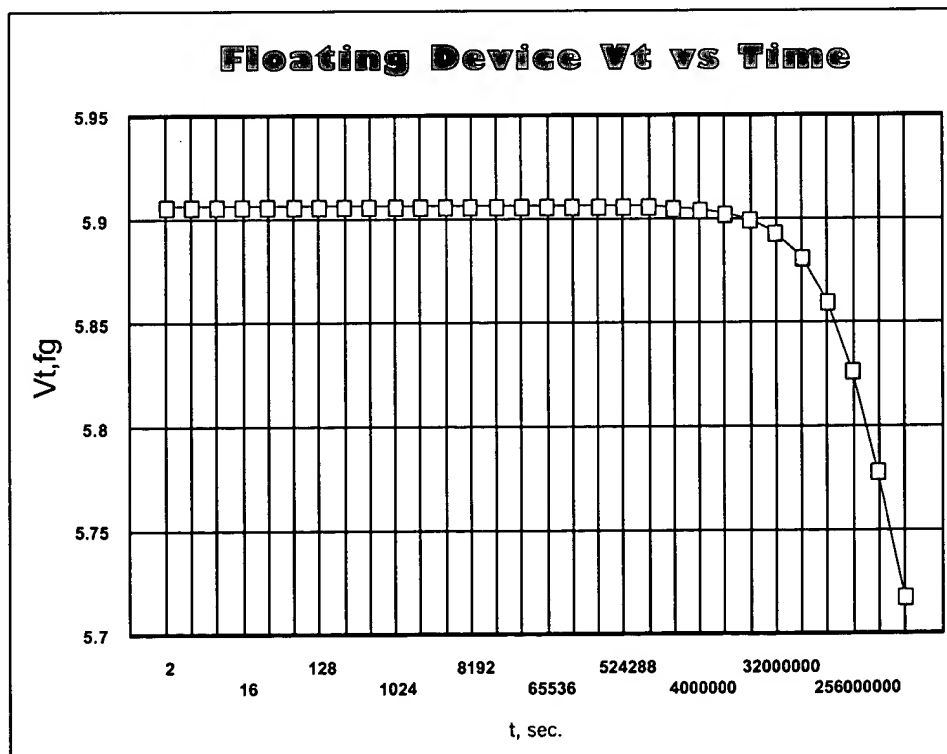
Calculation of memory cell retention characteristics

					Seconds	Time Period
q0, C	m0, kg	kb, J/K	h, J-s	hb, J-s	60	1 minute
1.6022E-019	9.1095E-031	1.38062E-023	6.62617E-034	.....	3600	1 hour
					86400	1 day
b0, eV (barrier) e1	mr, effective mass ratio		T, K degree		604800	1 week
2.9	3.9	0.5	300		2592000	1 month
					.....	1 year
C	b				.....	4 years
1.0630E-006	2.3854E+008				.....	16 years
					.....	32 years

Lfg um	0.6000	Channel length of floating gate device
Wfg um	1000.0000	Channel width of floating gate device.
Hfg um	0.0900	Thickness of floating gate polysilicon conductor
Wrx um	0.5000	Width of floating gate overlapping shallow trench isolation
Ttunox A	80	Tunnel oxide thickness
Tono A	190	Thickness of Oxide-Nitride-Oxide dielectric between floating gate and control gate for capacitive coupling
Tswox A	300	Thickness of sidewall oxide between floating gate and control gate for sidewall coupling
Xfd um	0.0500	Length of floating gate overlapping drain region of the floating gate MOSFET
Xfs um	0.3500	Length of floating gate overlapping source region of the floating gate MOSFET
Ainj um2	0.0438	Area of the electron tunneling region between the floating gate and the source for resetting the floating gate charge
Cfc fF	1089.5358	Capacitance between the floating gate and the control gate
Cfsx fF	0.4313	Capacitance between the floating gate and the silicon substrate
Cfd fF	0.1078	Capacitance between the floating gate and the drain
Cfs fF	0.7547	Capacitance between the floating gate and the source
Cfg fF	1090.8295	Total floating gate capacitance
Cr,wl	0.9988	Control gate to floating gate coupling ratio
Cr,src	0.0007	Source junction to floating gate coupling ratio
Vt,fg V	0.90	Threshold voltage of floating gate MOSFET
Verase	0.00	Erase voltage applied to the source(not used here, set to zero)
Vfg,ini	-5.00	Initial floating chaged voltage
Va	0.00	Actual erase volatge (equal to applied + charge stored on the floating)
S	3.76E+016	Derived parameter in the floating gate "erase" equation
X	1.27E+011	Derived parameter in the floating gate "erase" equation

t, sec. Vt,fg

0.00001	5.907
2	5.907
4	5.907
8	5.907
16	5.907
32	5.907
64	5.907
128	5.907
256	5.907
512	5.907
1024	5.907
2048	5.907
4096	5.907
8192	5.907
16384	5.907
32768	5.907
65536	5.907
131072	5.907
262144	5.907
524288	5.907
1000000	5.907
2000000	5.906
4000000	5.905
8000000	5.904
16000000	5.900
32000000	5.894
64000000	5.881
.....	5.860
.....	5.827
.....	5.779
.....	5.718



Figures 1G-1H

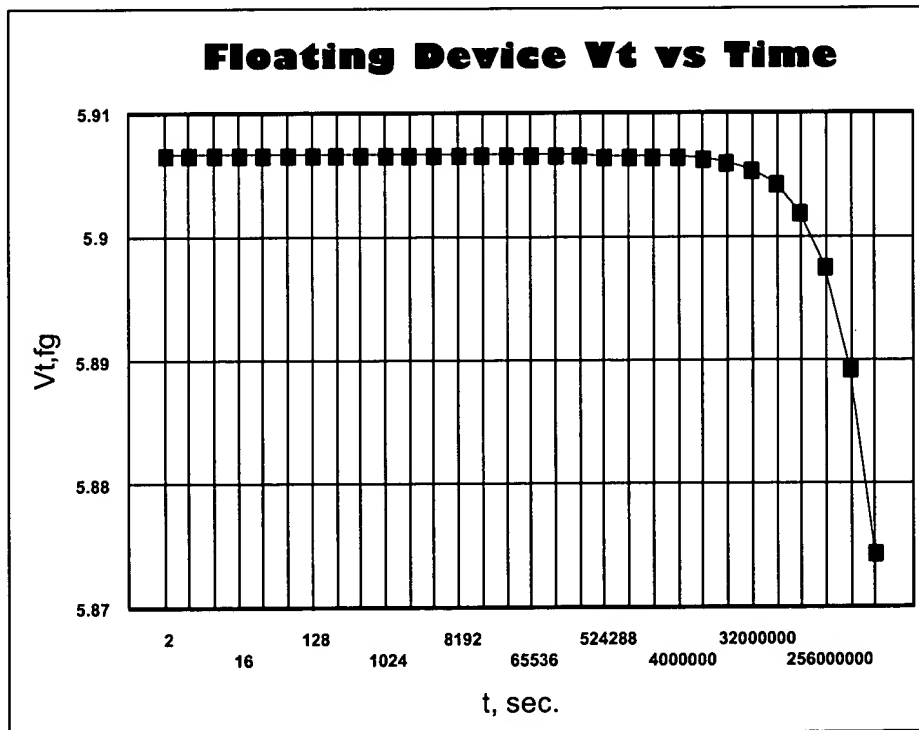
Calculation of nv memory cell retention characteristics

q0, C 1.6022E-019 m0, kg 9.1095E-031 kb, J/K 1.38062E-023 h, J-s 6.62617E-034 hb, J-s
 b0, eV (barrier)el 2.9 mr, effective mass ratio 3.9 T, K degree 300
 C 1.0630E-006 b 2.3854E+008

Seconds Time Period
 60 1 minute
 3600 1 hour
 86400 1 day
 604800 1 week
 2592000 1 month
 1 year
 4 years
 16 years
 32 years

Lfg um 0.6000 Channel length of floating gate device
 Wfg um 1000.0000 Channel width of floating gate device.
 Hfg um 0.0900 Thickness of floating gate polysilicon conductor
 Wrx um 0.5000 Width of floating gate overlapping shallow trench isolation
 Ttunox A 85 Tunnel oxide thickness
 Tono A 190 Thickness of Oxide-Nitride-Oxide dielectric between floating gate and control gate for capacitive coupling
 Tswox A 300 Thickness of sidewall oxide between floating gate and control gate for sidewall coupling
 Xfd um 0.0500 Length of floating gate overlapping drain region of the floating gate MOSFET
 Xfs um 0.3500 Length of floating gate overlapping source region of the floating gate MOSFET
 Ainj um2 0.0438 Area of the electron tunneling region between the floating gate and the source for resetting the floating gate c
 Cfc fF 1089.5358 Capacitance between the floating gate and the control gate
 Cfsx fF 0.4059 Capacitance between the floating gate and the silicon substrate
 Cfd fF 0.1015 Capacitance between the floating gate and the drain
 Cfs fF 0.7103 Capacitance between the floating gate and the source
 Cfg fF 1090.7534 Total floating gate capacitance
 Cr,wl 0.9989 Control gate to floating gate coupling ratio
 Cr,src 0.0007 Source junction to floating gate coupling ratio
 Vt,fg V 0.90 Threshold voltage of floating gate MOSFET
 Verase 0.00 Erase voltage applied to the source(not used here, set to zero)
 Vfg,ini -5.00 Initial floating charged voltage
 Va 0.00 Actual erase volatge (equal to applied + charge stored on the floating)
 S 4.09E+017 Derived parameter in the floating gate "erase" equation
 X 1.20E+011 Derived parameter in the floating gate "erase" equation

t, sec. Vt,fg
 0.00001 5.907
 2 5.907
 4 5.907
 8 5.907
 16 5.907
 32 5.907
 64 5.907
 128 5.907
 256 5.907
 512 5.907
 1024 5.907
 2048 5.907
 4096 5.907
 8192 5.907
 16384 5.907
 32768 5.907
 65536 5.907
 131072 5.907
 262144 5.907
 524288 5.907
 1000000 5.907
 2000000 5.907
 4000000 5.906
 8000000 5.906
 1.6E+007 5.906
 3.2E+007 5.905
 6.4E+007 5.904
 5.902
 5.898
 5.889
 5.874



Figures 1I-1J

The graph shows I_{Drain} on the vertical axis and V_{Gate} on the horizontal axis. A vertical dashed line marks V_{Read} . A series of seven curves are plotted, each representing a different time interval. As time increases, the curves shift to the left, indicating a decrease in the threshold voltage (V_{Thresh}). An arrow points to the left with the text "Decreasing V_{Thresh} ". Another arrow points to the left with the text "Increasing time" and "Decreasing floating gate charge".

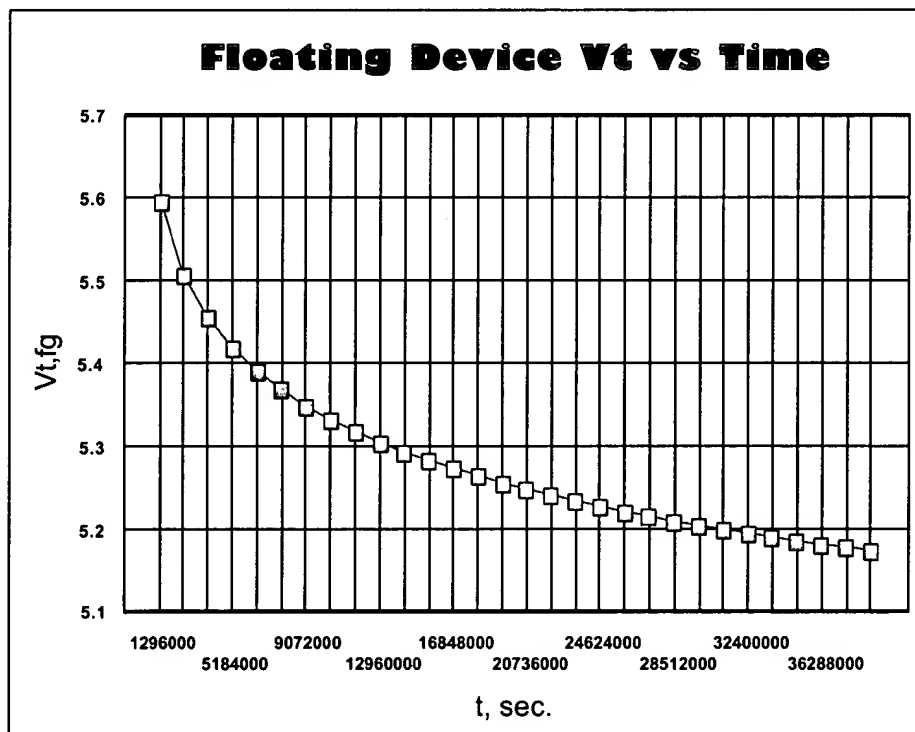
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Calculation of time cell retention characteristics

					Seconds	Time Period
q0, C	m0, kg	kb, J/K	h, J-s	hb, J-s	2592000	1 month
1.6022E-019	9.1095E-031	1.38062E-023	6.62617E-034	*****	5184000	2 months
					7776000	3 months
b0, eV (barrier)	εl	mr, effective mass ratio	T, K degree		*****	4 months
2.9	3.9	0.5	300	*****	*****	5 months
C	b				*****	6 months
1.0630E-006	2.3854E+008				*****	7 months
					*****	8 months
					*****	9 months
					*****	10 months
					*****	11 months
					*****	12 months
					*****	13 months
					*****	14 months
					*****	15 months
					*****	16 months

Lfg um	0.6000	Channel length of floating gate device
Wfg um	1000.0000	Channel width of floating gate device.
Hfg um	0.0900	Thickness of floating gate polysilicon conductor
Wrx um	0.5000	Width of floating gate overlapping shallow trench isolation
Ttunox A	65	Tunnel oxide thickness
Tono A	190	Thickness of Oxide-Nitride-Oxide dielectric between floating gate and control gate for capacitive coupling
Tswox A	300	Thickness of sidewall oxide between floating gate and control gate for sidewall coupling
Xfd um	0.0500	Length of floating gate overlapping drain region of the floating gate MOSFET
Xfs um	0.3500	Length of floating gate overlapping source region of the floating gate MOSFET
Ainj um ²	0.0438	Area of the electron tunneling region between the floating gate and the source for resetting the floating gate charge
Cfc fF	1089.5358	Capacitance between the floating gate and the control gate
Cfsx fF	0.5308	Capacitance between the floating gate and the silicon substrate
Cfd fF	0.1327	Capacitance between the floating gate and the drain
Cfs fF	0.9288	Capacitance between the floating gate and the source
Cfg fF	1091.1281	Total floating gate capacitance
Cr,wl	0.9985	Control gate to floating gate coupling ratio
Cr,src	0.0009	Source junction to floating gate coupling ratio
Vt,fg V	0.90	Threshold voltage of floating gate MOSFET
Verase	0.00	Erase voltage applied to the source(not used here, set to zero)
Vfg,ini	-5.00	Initial floating charged voltage
Va	0.00	Actual erase volatge (equal to applied + charge stored on the floating)
S	2.93E+013	Derived parameter in the floating gate "erase" equation
X	1.56E+011	Derived parameter in the floating gate "erase" equation

t, sec.	Vt,fg
0.00001	5.909
1296000	5.596
2592000	5.508
3888000	5.456
5184000	5.420
6480000	5.392
7776000	5.369
9072000	5.349
*****	5.333
*****	5.318
1.3E+007	5.305
*****	5.293
*****	5.283
*****	5.273
*****	5.264
*****	5.256
*****	5.248
2.2E+007	5.240
*****	5.234
*****	5.227
*****	5.221
*****	5.215
*****	5.210
*****	5.204
*****	5.199
*****	5.195
*****	5.190
3.5E+007	5.185
*****	5.181
*****	5.177
*****	5.173



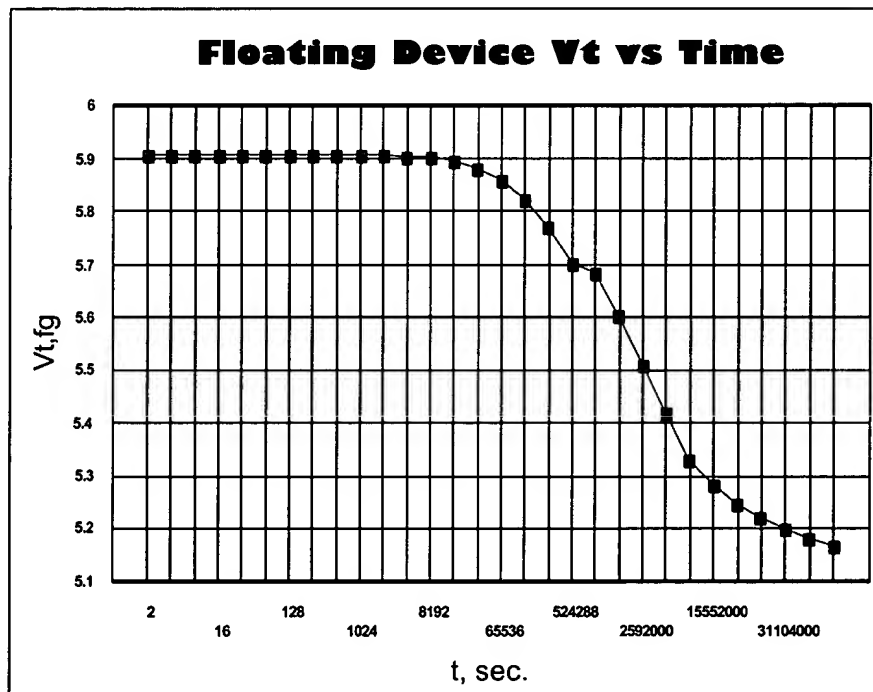
Figures 1L-1M

Calculation of time cell retention characteristics

					Seconds	Time Periods
q0, C	m0, kg	kb, J/K	h, J-s	hb, J-s	60	1 minute
1.6022E-019	9.1095E-031	1.38062E-023	6.62617E-034	1.054588E-034	3600	1 hour
					86400	1 day
b0, eV (barrier)	el	mr, effective mass ratio	T, K degree		604800	1 week
2.9	3.9	0.5	300		1209600	2 weeks
					2592000	1 month
C	b				5184000	2 months
1.0630E-006	2.3854E+008				10368000	4 months
					15552000	6 months
					20736000	8 months
					25920000	10 months
					31104000	12 months
					36288000	14 months
					41472000	16 months

Lfg um	0.6000	Channel length of floating gate device
Wfg um	1000.0000	Channel width of floating gate device.
Hfg um	0.0900	Thickness of floating gate polysilicon conductor
Wrux um	0.5000	Width of floating gate overlapping shallow trench isolation
Ttunox A	65	Tunnel oxide thickness
Tono A	190	Thickness of Oxide-Nitride-Oxide dielectric between floating gate and control gate for capacitive coupling
Tswox A	300	Thickness of sidewall oxide between floating gate and control gate for sidewall coupling
Xfd um	0.0500	Length of floating gate overlapping drain region of the floating gate MOSFET
Xfs um	0.3500	Length of floating gate overlapping source region of the floating gate MOSFET
Ainj um ²	0.0438	Area of the electron tunneling region between the floating gate and the source for resetting the floating gate charge
Cfc fF	1089.5358	Capacitance between the floating gate and the control gate
Cfsx fF	0.5308	Capacitance between the floating gate and the silicon substrate
Cfd fF	0.1327	Capacitance between the floating gate and the drain
Cfs fF	0.9288	Capacitance between the floating gate and the source
Cfg fF	1091.1281	Total floating gate capacitance
Cr,wl	0.9985	Control gate to floating gate coupling ratio
Cr,src	0.0009	Source junction to floating gate coupling ratio
Vt,fg V	0.90	Threshold voltage of floating gate MOSFET
Verase	0.00	Erase voltage applied to the source(not used here, set to zero)
Vfg,ini	-5.00	Initial floating charged voltage
Va	0.00	Actual erase voltage (equal to applied + charge stored on the floating)
S	2.93E+013	Derived parameter in the floating gate "erase" equation
X	1.56E+011	Derived parameter in the floating gate "erase" equation

t, sec.	Vt,fg
0.00001	5.909
2	5.909
4	5.909
8	5.909
16	5.909
32	5.909
64	5.909
128	5.909
256	5.908
512	5.908
1024	5.908
2048	5.907
4096	5.905
8192	5.902
16384	5.895
32768	5.883
65536	5.861
131072	5.824
262144	5.771
524288	5.702
1048576	5.686
2097152	5.604
4194304	5.508
8388608	5.420
16777216	5.333
33554432	5.283
67108864	5.248
134217728	5.221
268435456	5.199
536870912	5.181
1073741824	5.166



Figures 1N-10

7/22

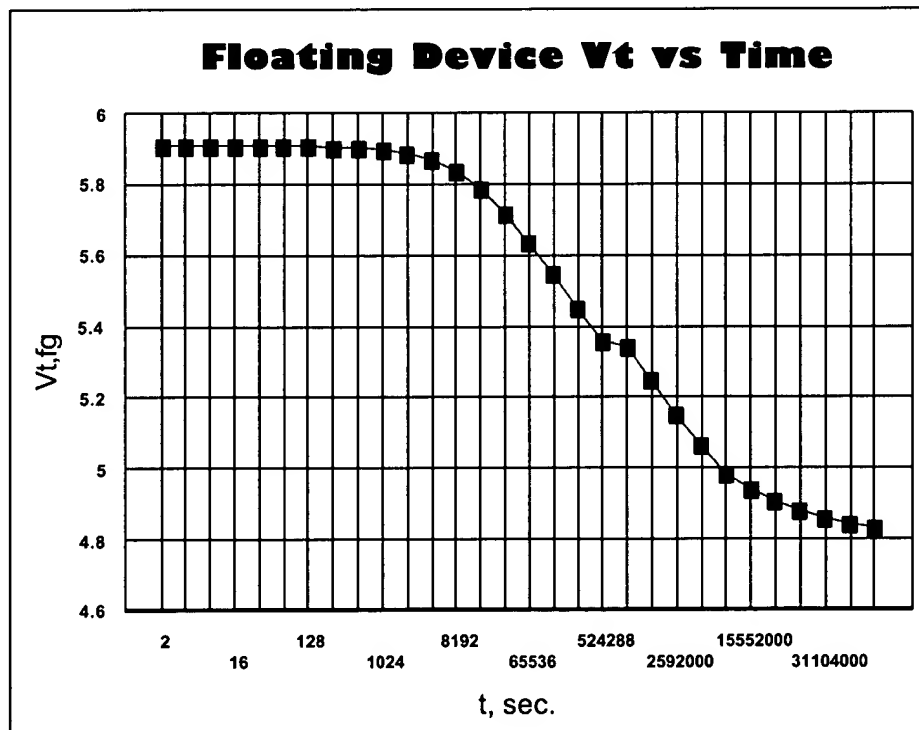
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Calculation of time cell retention characteristics

					Seconds	Time Period
q0, C	m0, kg	kb, J/K	h, J-s	hb, J-s	60	1 minute
1.6022E-019	9.1095E-031	1.38062E-023	6.62617E-034	*****	3600	1 hour
					86400	1 day
b0, eV (barrier)	el	mr, effective mass ratio	T, K degree		604800	1 week
2.9		3.9	0.5	300	1209600	2 weeks
					2592000	1 month
C	b				5184000	2 months
1.0630E-006	2.3854E+008				*****	4 months
					*****	6 months
					*****	8 months
					*****	10 months
					*****	12 months
					*****	14 months
					*****	16 months

Lfg um	0.6000	Channel length of floating gate device
Wfg um	1000.0000	Channel width of floating gate device.
Hfg um	0.0900	Thickness of floating gate polysilicon conductor
Wrx um	0.5000	Width of floating gate overlapping shallow trench isolation
Ttunox A	60	Tunnel oxide thickness
Tono A	190	Thickness of Oxide-Nitride-Oxide dielectric between floating gate and control gate for capacitive coupling
Tswox A	300	Thickness of sidewall oxide between floating gate and control gate for sidewall coupling
Xfd um	0.0500	Length of floating gate overlapping drain region of the floating gate MOSFET
Xfs um	0.3500	Length of floating gate overlapping source region of the floating gate MOSFET
Ainj um ²	0.0438	Area of the electron tunneling region between the floating gate and the source for resetting the floating gate charge
Cfc fF	1089.5358	Capacitance between the floating gate and the control gate
Cfsx fF	0.5750	Capacitance between the floating gate and the silicon substrate
Cfd fF	0.1438	Capacitance between the floating gate and the drain
Cfs fF	1.0063	Capacitance between the floating gate and the source
Cfg fF	1091.2608	Total floating gate capacitance
Cr,wl	0.9984	Control gate to floating gate coupling ratio
Cr,src	0.0009	Source junction to floating gate coupling ratio
Vt,fg V	0.90	Threshold voltage of floating gate MOSFET
Verase	0.00	Erase voltage applied to the source(not used here, set to zero)
Vfg,ini	-5.00	Initial floating charged voltage
Va	0.00	Actual erase volatge (equal to applied + charge stored on the floating)
S	2.70E+012	Derived parameter in the floating gate "erase" equation
X	1.69E+011	Derived parameter in the floating gate "erase" equation

t, sec.	Vt,fg
0.00001	5.909
2	5.909
4	5.909
8	5.909
16	5.909
32	5.909
64	5.909
128	5.908
256	5.907
512	5.904
1024	5.898
2048	5.888
4096	5.870
8192	5.838
16384	5.789
32768	5.721
65536	5.639
131072	5.549
262144	5.455
524288	5.360
604800	5.341
1209600	5.250
2592000	5.152
5184000	5.067
*****	4.985
*****	4.938
*****	4.906
*****	4.881
*****	4.861
*****	4.844
*****	4.830



Figures 1P-1Q

8/22

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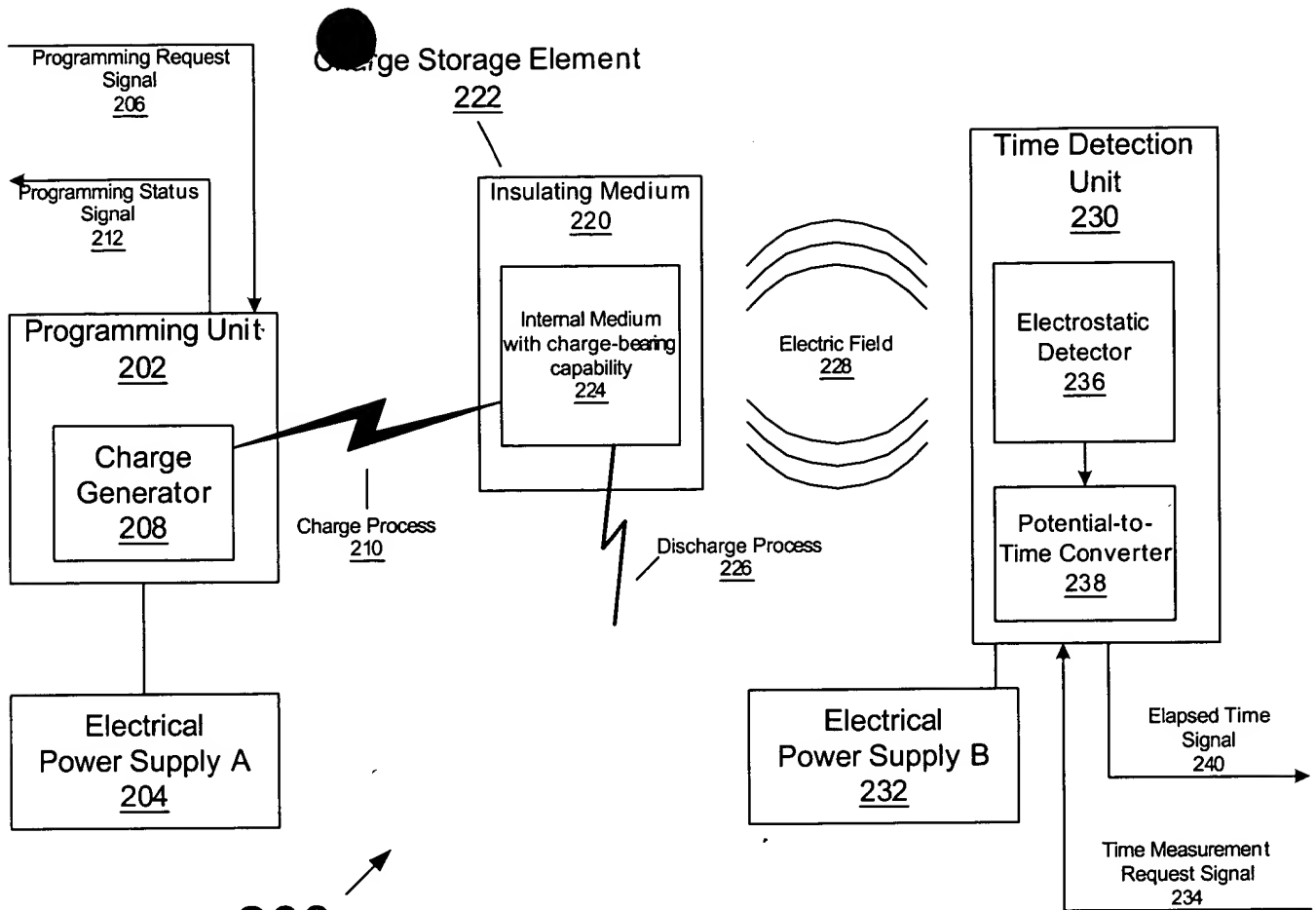


Figure 2A

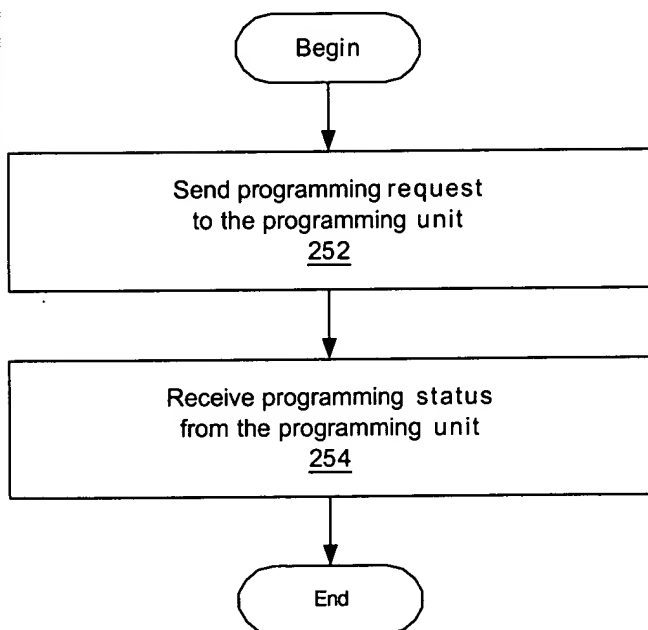


Figure 2B

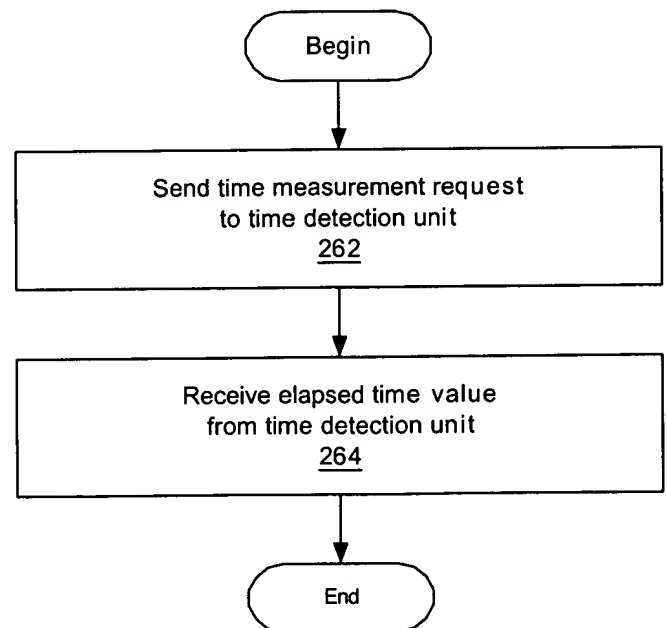


Figure 2C

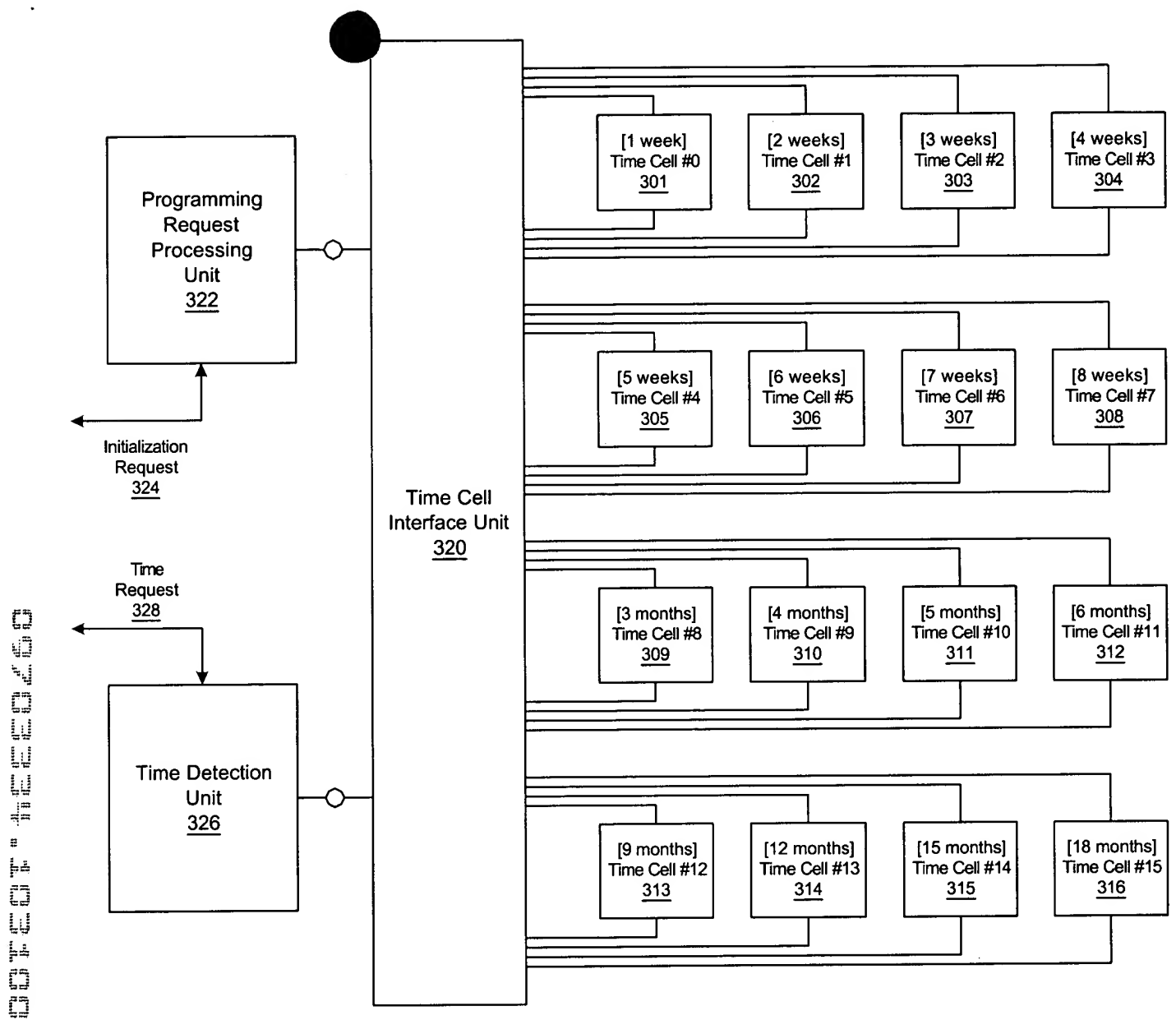


Figure 3A

007607-1660460

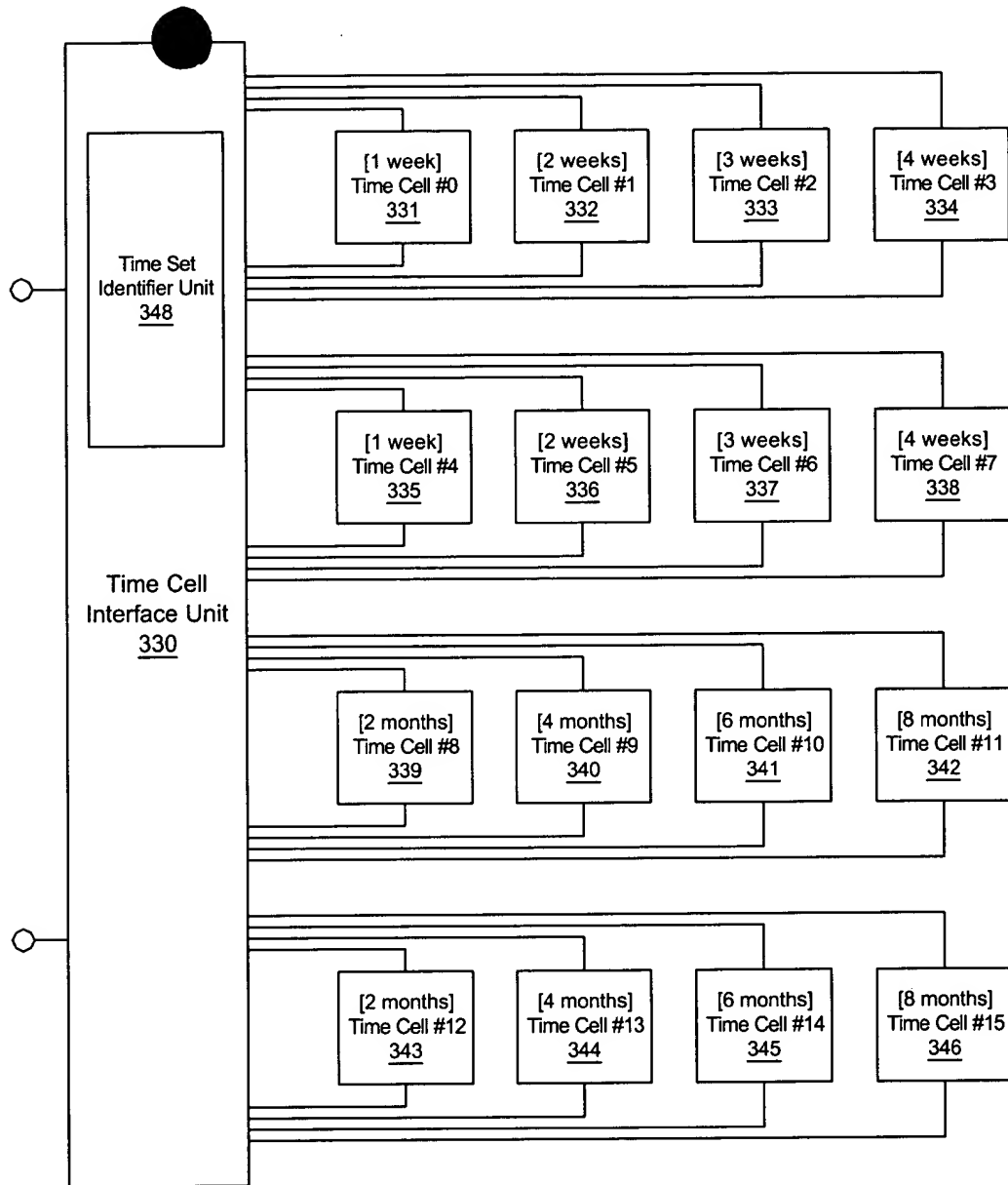


Figure 3B

SECRET REF ID: A66260

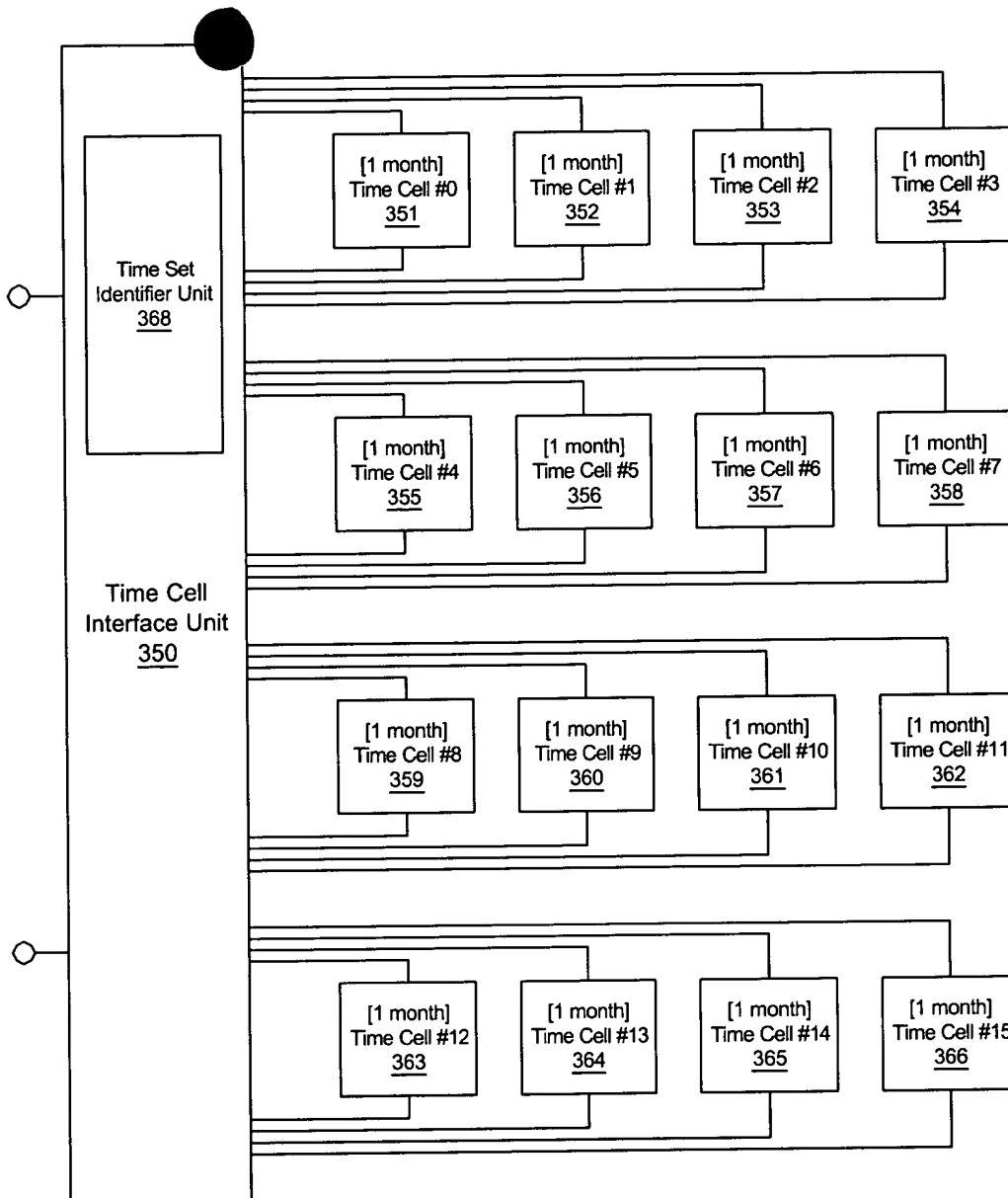


Figure 3C

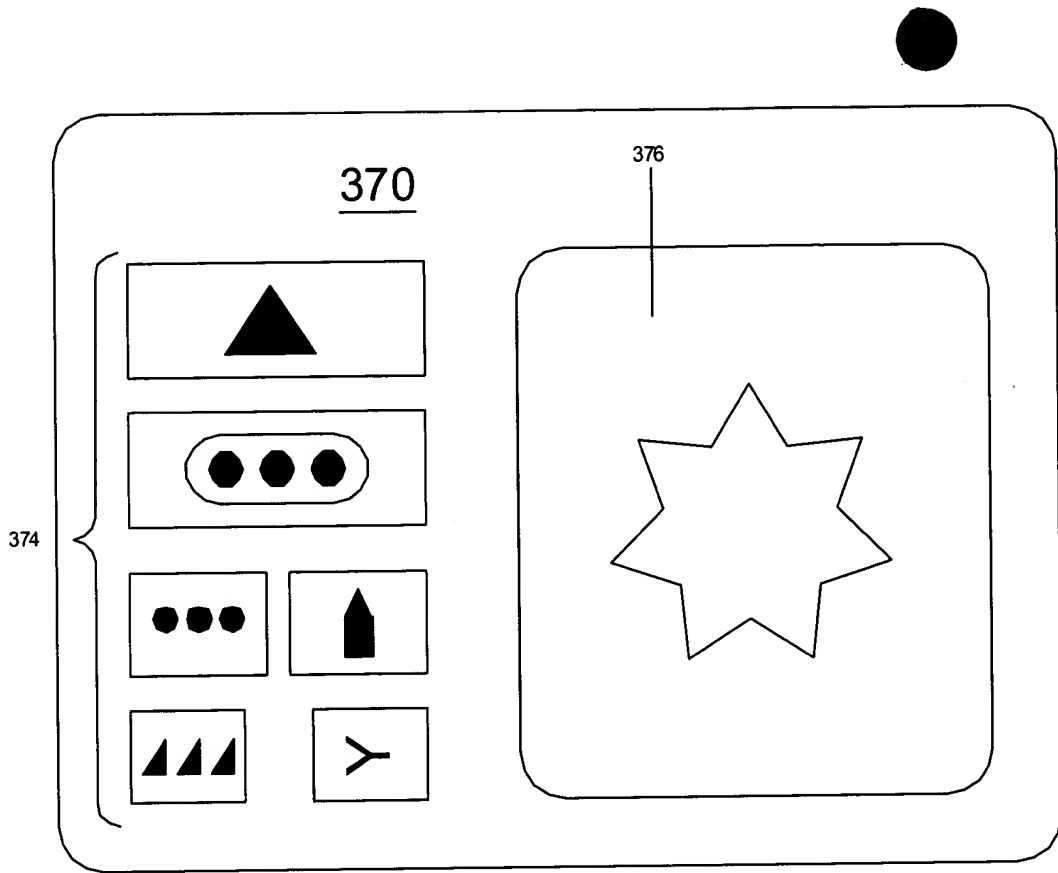


Figure 3D

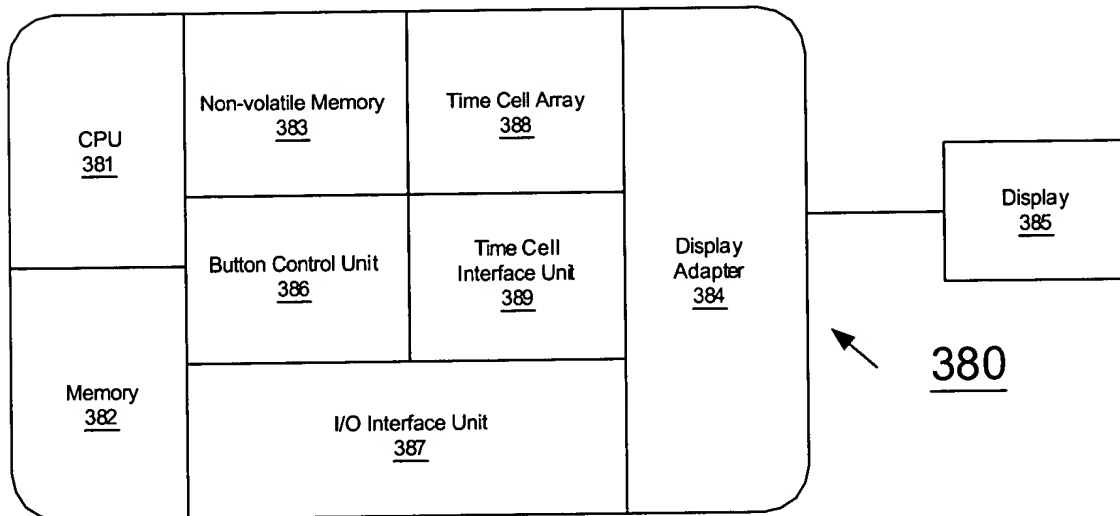


Figure 3E

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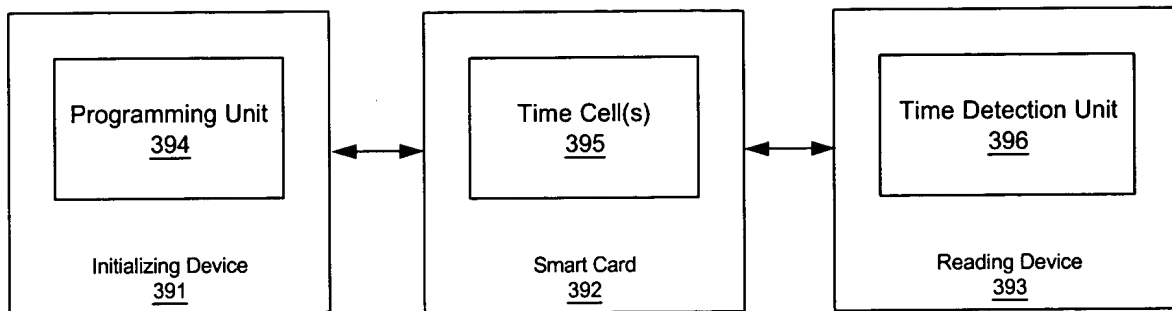
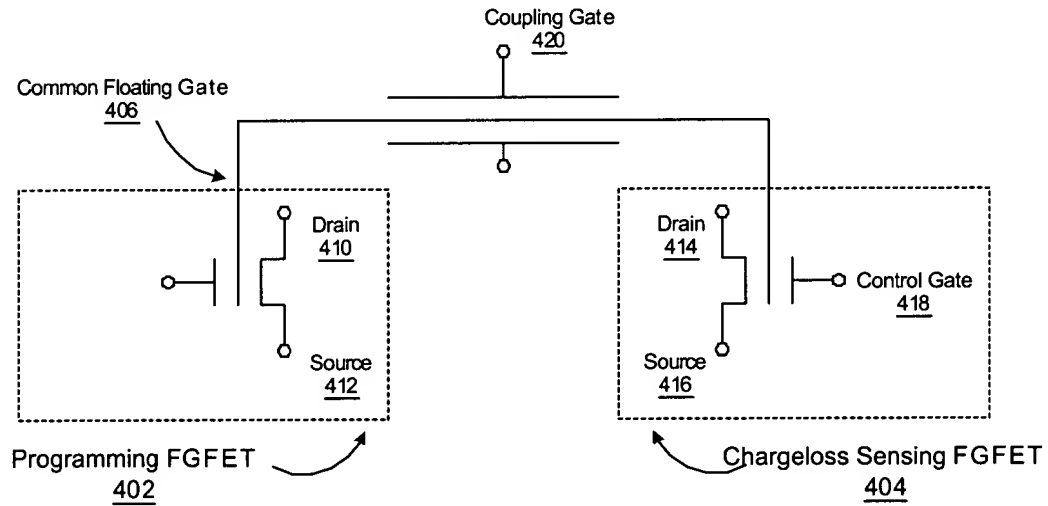
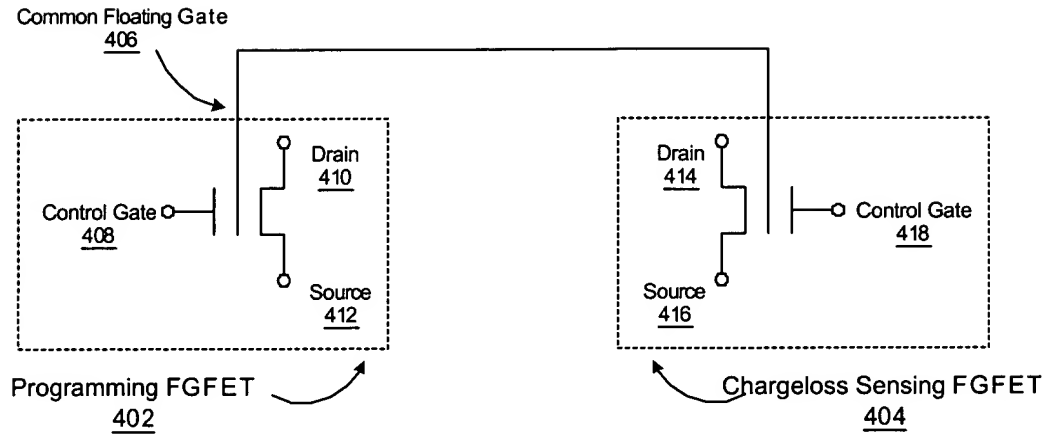


Figure 3F

007607-11EED260



Voltages during programming operation

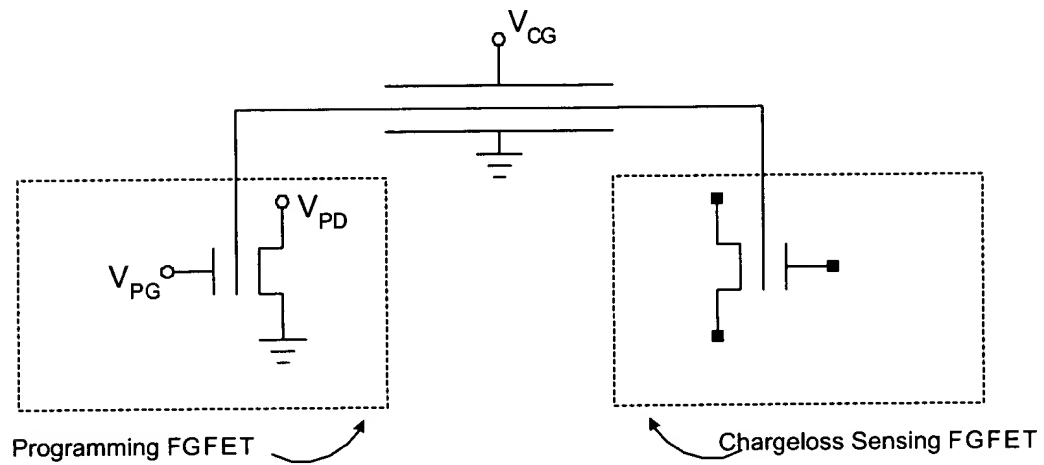


Figure 4C

Voltages during sensing operation

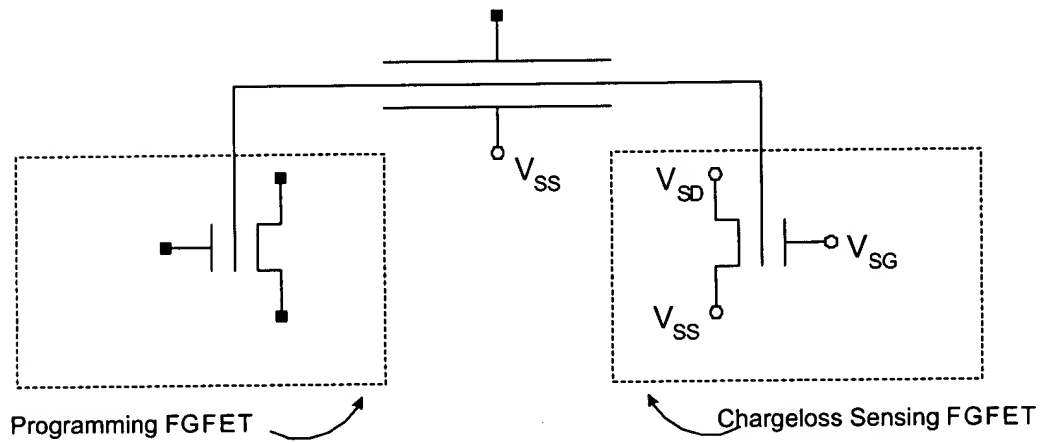


Figure 4D

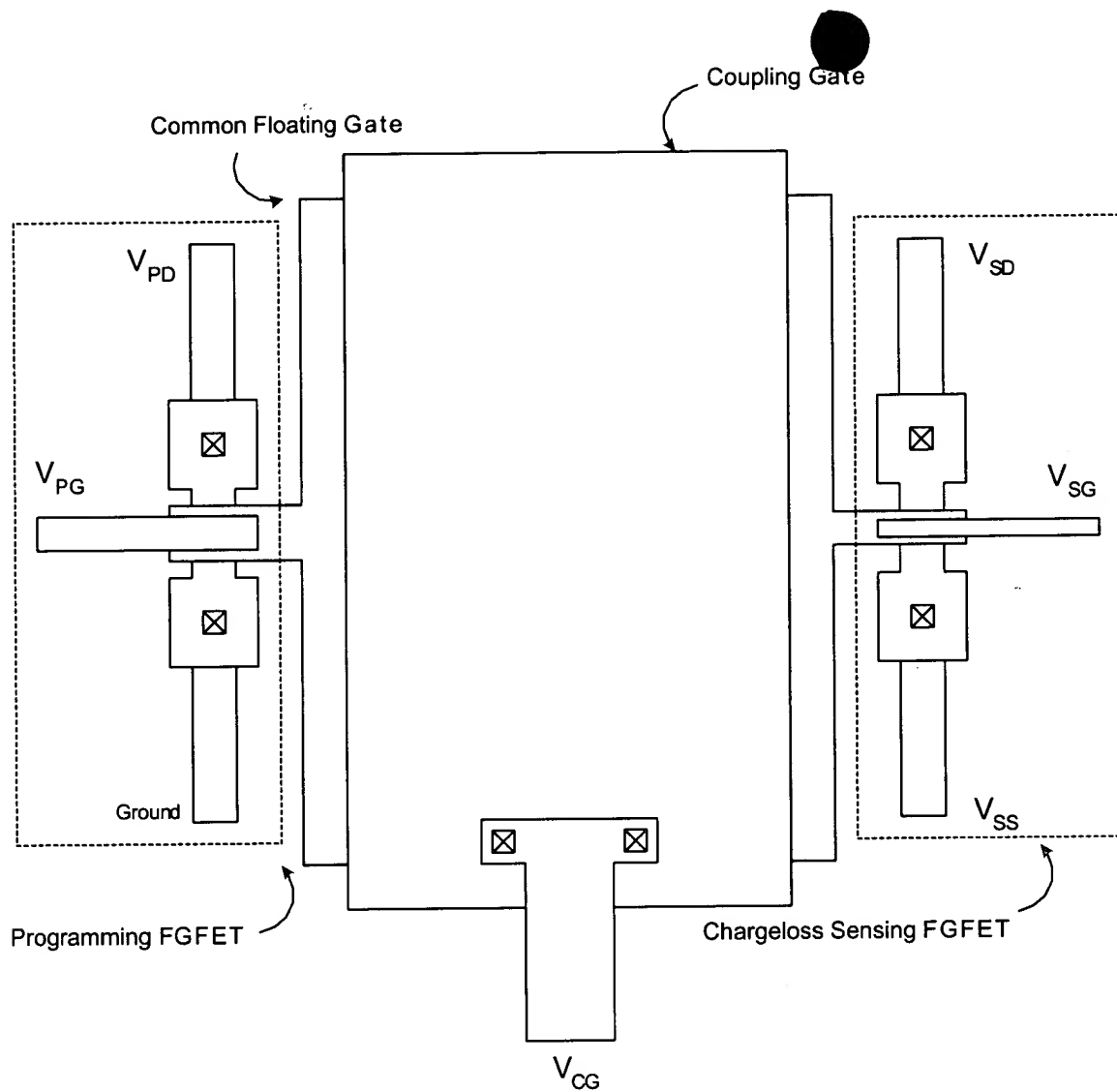


Figure 4E

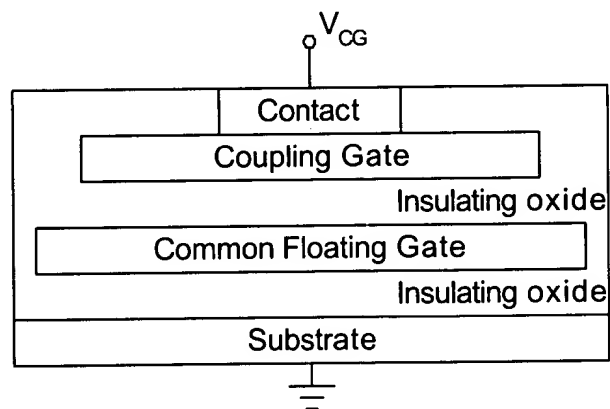


Figure 4F

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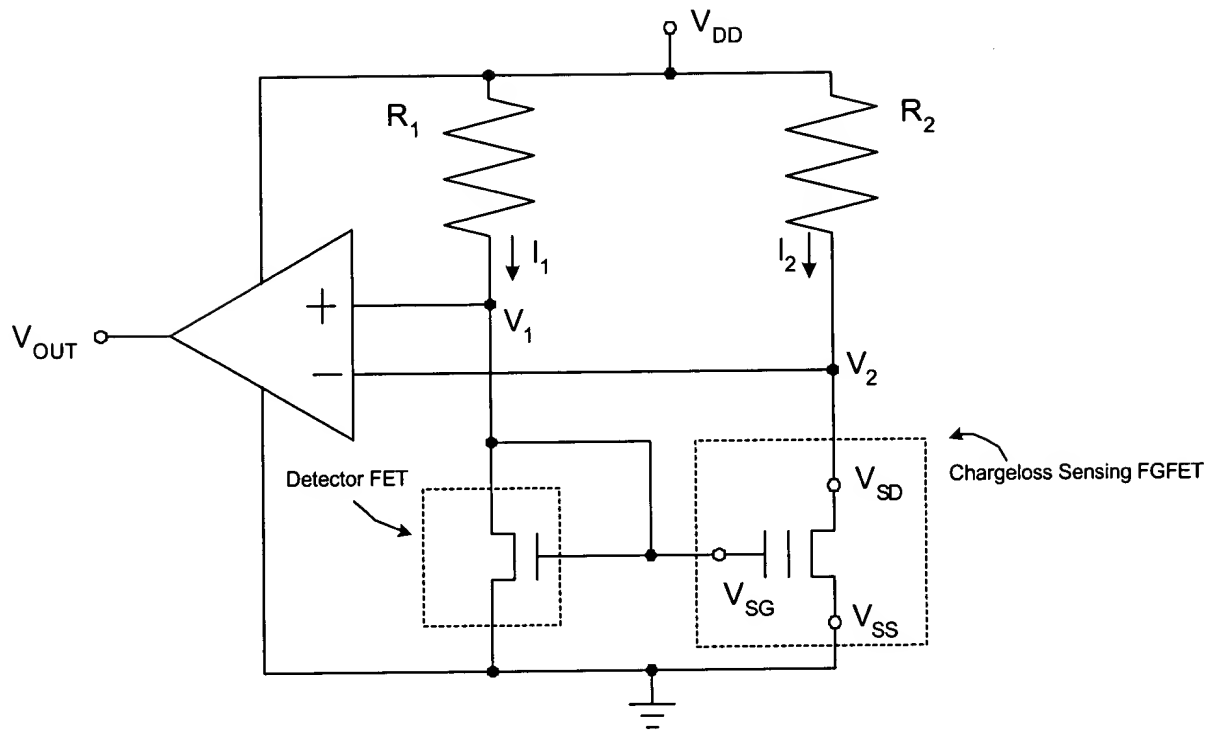


Figure 4G

A graph showing Voltage (V) on the vertical axis and Time on the horizontal axis. A horizontal line marks the $V_{\text{Threshhold}}$ level. A curve starts at this threshold level and decays exponentially towards zero as time increases.

A graph showing the relationship between Drain Current (I_{Drain}) on the vertical axis and Time on the horizontal axis. The curve starts at the origin (0,0) and increases monotonically with a decreasing slope, characteristic of an exponential growth function.

A graph showing the output voltage V_{Out} versus Time. The vertical axis is labeled V_{Out} and the horizontal axis is labeled Time. A horizontal dashed line represents the supply voltage V_{DD} . The output voltage starts at 0 and rises exponentially towards V_{DD} .

19/22
Aus 92000-0734(US)

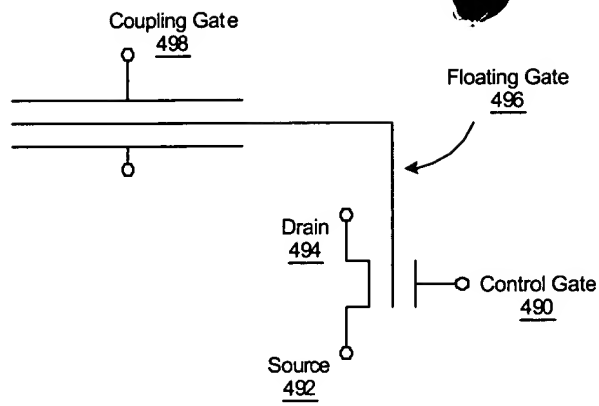


Figure 4M

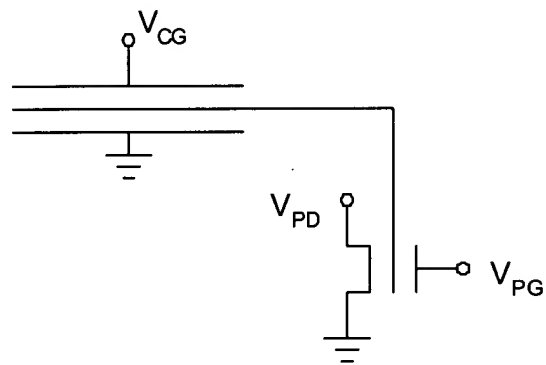


Figure 4N

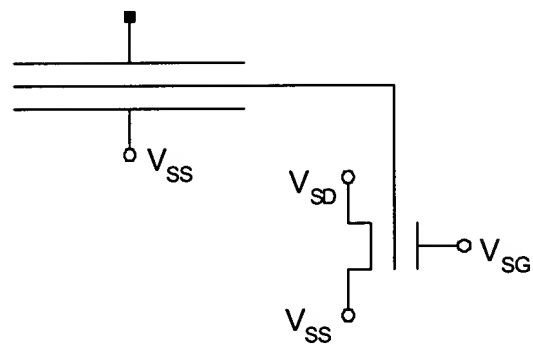


Figure 4O

The diagram illustrates the layout of a 1T1C1D transistor. A large central rectangle represents the **Floating Gate**. To its right, a vertical channel connects the **Drain** (top) and **Source** (bottom) regions. This channel is controlled by a **Control Gate**, shown as a horizontal bar. Two **Coupling Gates**, represented by small squares with an 'X', are located on the bottom edge of the floating gate, connected to the source region. Arrows point from the labels to their respective components.

22/22

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